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ENDOGENOUS MONEY –A STRUCTURAL MODEL OF MONETARY BASE

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April 2011

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ABSTRACT

In this paper we develop a structural monetary base model. An important feature of this approach is that the model combines three parts of the determinants of the monetary base. The three parts are the commercial bank, the public and the central bank. Bank behaviour relies on an explicit specification of a maximum profit-seeking and risk-averse model which describes the determinants of the supply of deposits by banks as well as their demands for earning assets and （free） reserves. The behaviours of the public and central bank are set up exogeneously. According to the structural model, we derive the monetary base equation which is determined by various financial and real variables endogenously.

Keywords: Endogenous, Monetary base, Post Keynesian（PK）economics.

1. Introduction

Many central banks adopt the monetary targeting regime to stabilise the price level by directly controlling money supply, which is achieved by managing the quantity of central bank money (monetary base). The quantity of monetary base is the operational target while money supply is the intermediate target under a monetary targeting regime. Its success depends heavily on the controllability of money supply and the monetary base. However, there is very little reason to rely on the stability of the money multiplier and the controllability of the monetary base by the monetary authorities (Khan, 2010；Goodhart, 1989).

Traditionally, the supply of money has been regarded as exogenous. Within orthodox monetary macroeconomics, the determination of money supply is widely viewed as unproblematic. Macroeconomists either believe money supply to be endogenous, or believe it can be controlled. However, the facts seem to lie somewhere between these positions (Ashima and Shridhar, 2000). The Post Keynesian (PK) economists have seriously questioned the validity of the above general perception. On the basis of historical events and empirical evidences, researchers have strongly maintained that money supply is determined endogenously. This has been regarded as Post Keynesian invention. Money has always been endogenous, irrespective of the historical period. Money is endogenous irrespective of the central bank, the specific stage of development of the banking sector, financial innovations, or other institutional changes (Rochon and Rossi, 2006).

The endogeneity view is supported by Bundesbank, UK data, and Fed:(i) In the 24 years of monetary targeting from 1975 to 1998, the explanations of the Bundesbank for the differences between the announced target and observed money growth rate since 1992/93 refer to unforeseen changes in the demand for money, implying that the endogenous money stock has been determined by the demand for money. This supports the endogeneity view (Holtem¨oller, 2002).(ii) The estimation of Mariscal and Howells (2010) shows that the reason of high volatility around a declining trend for income velocity (PY/M) in recent years for many countries including UK is endogeneity of broad money. (iii) A Staff Working Paper in the Finance and Economics Discussion Series of the Federal Reserve System mentioned that most models currently used for macroeconomic policy analysis either exclude money or model money demand as entirely endogenous(Carpenter and Demiralp, 2010).

Theoretically, the monetary base will be reduced when the Central Bank issues CDs to banks. However, Figure 1 shows that their trends are in the same direction. That means that the monetary base is not easily controlled and dependent on banks' behaviour or is endogenous .

Figure 1
Monetary Base and Amounts Outstanding of CDs Issued by the Central Bank

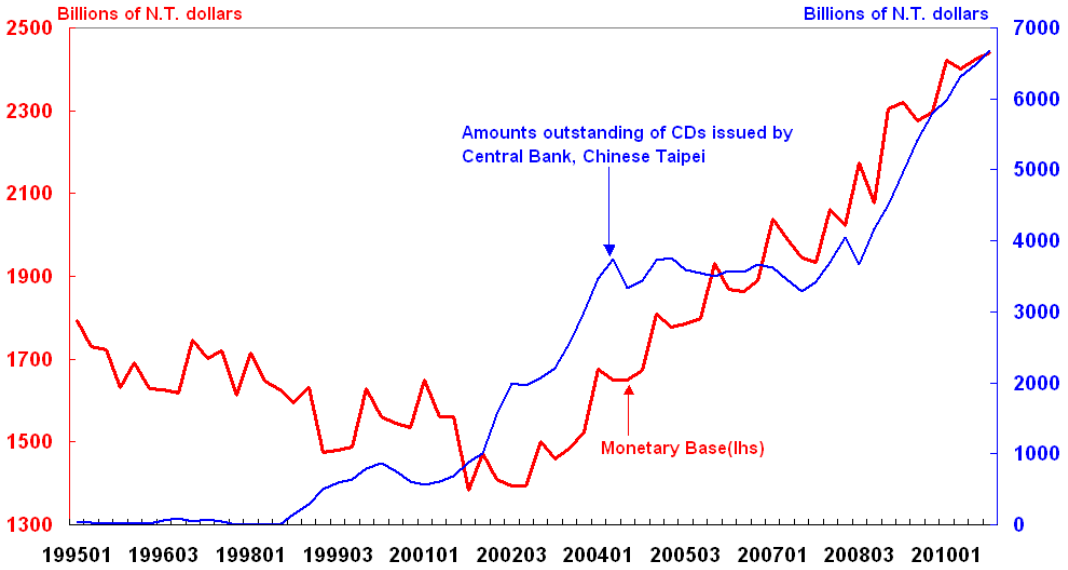
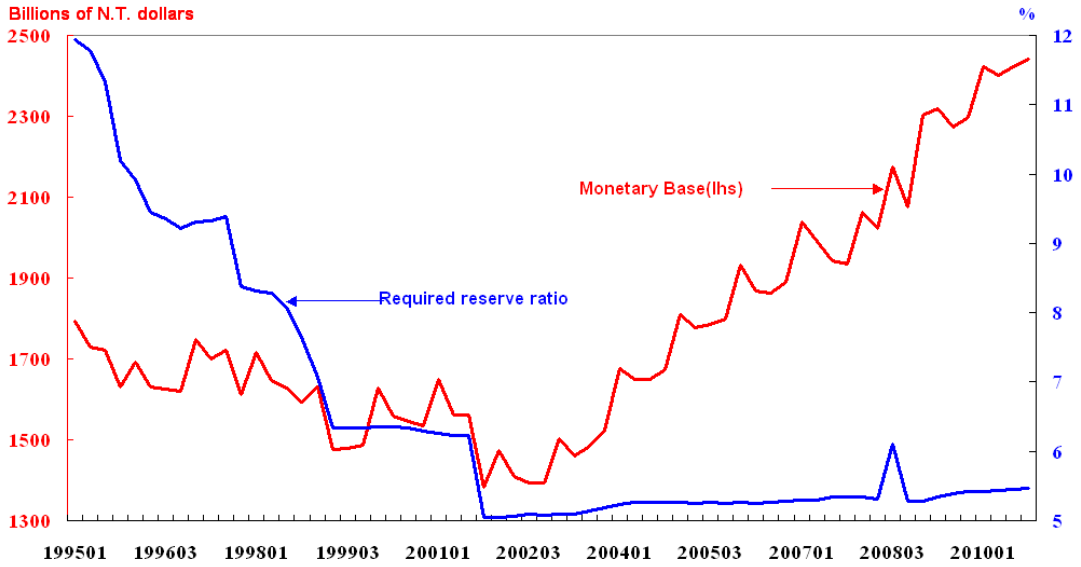


Figure 2 shows that the trends of required reserve ratio（z）and the monetary base (MB) seem to be in the same direction. They are consistent with the findings of Montoro and Moreno (2011). They stated that reserve requirements can potentially act countercyclically, smoothing out liquidity fluctuations in the financial system over time and smoothing credit growth. Financial intermediation (measured by the ratios of M2 to GDP and of domestic credit to GDP) indeed tends to be lower when the level of reserve requirements is higher. This implies that required reserve ratio affect the multiplier and MB in different directions and magnitude. As Holtem¨oller (2002) supports the endogeneity view for the explanations of the Bundesbank, the differences between the announced target and observed monthly money growth rate from 2007 to 2009 imply that the existence of an endogenous monetary base in Chinese Taipei.

Figure 2
Required Reserve Ratio（z）and Monetary Base（MB）



In this paper, we develop a structural monetary base model which focuses explicitly on the role of bank liquidity management. An important feature of this approach is that the model combines three parts of the determinants of the monetary base. The three parts are the commercial bank, the public and the central bank. This approach focuses on the interaction between bank behaviour, central bank behaviour and the public's asset choice behaviour.

The paper is structured as follows. In Section 2, literature on endogenous money is briefly reviewed. In Section 3, a structural model of monetary base is developed. In Section 4, comparative statistics analysis is delved into. Finally, Section 5 is the conclusion.

2. Literature Review

In this Section, we review literature of the money multiplier approach, new view models, Post Keynesian economics and some empirical literature.

2.1 Money Multiplier Approach

Generally, two conflicting views of money supply can be found in the literature. The older one is the money multiplier approach (Friedman and Schwartz, 1963). The other view is the so-called "New View" (Holtem¨oller, 2002；Papademos and Modigliani, 1990；Santomero,1984；Baltensperger,1980；Klein,1971).

The money multiplier approach is the "Old View" of money supply. Money stock is determined by the money multiplier and the monetary base is controlled by the monetary authority. Money stock is exogenous and controllable by the monetary authority. The exogeneity or controllability assumption of the money multiplier approach forms the basis of the monetary policy strategy of monetary targeting. Three

factors are considered as proximate determinants of money supply as suggested by Friedman and Schwartz (1963), which are: a) the stock of high-powered money; b) the ratio of deposit to reserve; c) the ratio of deposit to currency.

The variations in money multiplier depend on the currency in circulation, demand deposits, time deposits and bank reserves. Variations in these factors may dominate in the money stock in the short-run and become stable and predictable over the long-run. The non-monetarist has pointed out that these factors are determined by the portfolio behaviour of agents and are sensitive to changes in relative rates of return, risk, innovations in the financial markets, income and preferences of the market participants.

However, the money multiplier approach does not necessarily imply exogeneity of the money stock (Holtem¨oller, 2002). If the money multiplier exhibits unpredictable and endogenous variations, the money stock is endogenous.

With the increasing role of market forces in the financial transactions and continuous improvements in asset-liability management, there is very little reason to be reliant on the stability of the money multiplier and the controllability of the monetary base by monetary authorities (Goodhart, 1989). Jha and Rath (2001) argues that an endogenous money multiplier framework is best suited for analysing the money supply process in India and finds instability on the part of both narrow and broad money multipliers, implying the uncontrollability and endogeneity of money.

The proponents of Keynesian theory argue that if the central bank tries to increase aggregate demand by open market purchase, this will not be possible because the public would not accept real cash balance more than their needs and portfolio requirements (Ali and Islam, 2010).

2.2 New View Models

The New View stresses the importance of commercial banks in the money supply process. According to this view, money stock and the monetary base are endogenous, resulting from the optimizing behaviour of commercial banks and the public given the monetary reaction function set by the monetary authority. The central bank is not able to control the money stock (Holtem¨oller, 2002). With some additional assumptions that the New View models could be employed to analyse the macroeconomic implications of imperfect competition in credit markets (Himanshu and Bhattacharyya, 2003).

In a modern financial system, Papademos and Modigliani(1990) recognise the central bank cannot control money supply directly but only indirectly by influencing the behaviour of financial intermediation (notably banks). They describe the money supply mechanism as a structural model of money stock determination. The determination of money supply relies on an explicit specification of a structural model of bank behaviour which describes the determinants of the supply of deposits by banks as well as their demands for earning assets and free reserves. The model of bank behaviour is then combined with equations describing the determinants of the demands for currency, bank deposits and bank loans by the public to obtain a complete model of the money market determining the stock of money and one or

more interest rates. The main advantage of this approach is that it explicitly specifies the mechanism through which the interaction of the public's demands for assets, the banks' behaviour and the central bank's actions determine the stock of money. The multiplier approach, even when it allows for interest rate effects, leads to a money supply specification which is a hybrid of elements of public demand and bank behaviour, a kind of semi-reduced form rather than a money supply specification. It does not provide a theoretical analysis of the process through which banks' behaviour influences the supply of bank deposits.

2.3 Post Keynesian（PK）Economics

Endogenous money theory is one of the main cornerstones of PK economics and a widely discussed topic, especially in New and PK macroeconomics (Fontana, 2003；Georg and Pasche, 2010). Endogenous money represents a mainstay of PK macroeconomics. In Post Keynesian economics, money is endogenous by its nature. The PK theory of endogenous money constitutes a significant contribution to macroeconomic theory. Analytically, it provides a critical link connecting the financial and real sectors. PK endogenous money theory emphasises that this linkage runs predominantly from credit to money to economic activity. The important feature is that credit is placed at the beginning of this sequence. This contrasts with conventional representations that place money first, as reflected in the standard textbook money multiplier story where bank deposits are said to create loans. The origins of PK endogenous money lie directly opposite that of monetarism. Whereas neo-Keynesian economics challenged monetarism by focusing on the optimality of money supply versus interest rate targets, PK theory challenged monetarism's description of the money supply process (Palley, 2008).

PK's essence is that the stock of money in an economy is determined by the demand for bank credit, and the latter is causally dependent upon the economic variables that affect the level of output. Why does money exist and what does money do? Why do economic agents hold money and to what ends? How do economic agents use money and for what purpose? All these questions have stimulated several studies and led to the development of a variety of PK models and assumptions. Holtem¨oller (2002) also describes that both the money stock and the monetary base are determined endogenously by the optimising behaviour of commercial banks and private agents like households and firms.

Endogenous money has been given kudos for proposing a variety of perspectives from which the above questions could be answered. It can be taken as a common conviction that individual behaviour regarding credit demand and supply as well as holding currency and deposits, has an impact on the money creation process. These issues are often neglected in Neoclassical and Monetarist type models. There are, however, very different approaches on how endogeneity of money originate. New Keynesian economics is dominated by the "New Consensus" where the exogenously determined money supply of the central bank (LM curve) is replaced by the Taylor rule. The monetary policy targets inflation and output gap by controlling the real interest rate, while there is no explicit theory about the creation of credit and money (Georg and Pasche, 2010).

2.3.1 Accommodationist (or Horizontalist) and Structuralist Approaches

Figure 3 depicts the money supply process (Palley, 2008, 1993). PK theory is itself divided between accomodationist (or horizontalist) and structuralist approaches to money supply. What both schools have in common is that the money creation process is determined by the behaviour of commercial banks and non-banks in the credit market. The process starts with credit demand, and credit creating deposits.

The accomodationist (or horizontalist) argues that an increase in credit demand leads to a need for additional reserves. In order to ensure the liquidity of the banking sector, the central bank has to respond by increasing the monetary base and hence to accomodate the credit demand. In this view, the microeconomic considerations of the commercial banking sector play a minor role. The accomodationist believes the behaviour of financial institutions is unconstrained by the availability of liquidity (reserves) provided by the central bank and the supply-price of finance to banks is fixed at a price set by the central bank.

In contrast, the structuralist approach argues that commercial banks respond to an increase in credit demand with structural changes of their portfolio on the asset and liability side. This may lead to a change in the demand for reserves and hence in the interaction with the central bank. Structuralists believe that liquidity pressures matter and the supply price of finance to banks can increase endogenously (Georg and Pasche, 2010).

Horizontalists can be divided into those having “strong” and “weak” positions. The strong position holds that the bank loan supply schedule is horizontal and interest rates are unaffected by lending. On the other hand, the weak position states that interest rates may rise with lending if borrower quality deteriorates.

The core of endogenous money theory is that the supply of money in modern economies is determined by the demand for credit (bank loans) and that this, in turn, responds to the need for financing production or speculative purchases. Beyond a widespread agreement over the idea that ‘loans create deposits’ and ‘deposits make reserves’, there is much controversy (Fontana, 2004). At the heart of the debate between what have now been labelled the accommodationist (or horizontalist) approach and the structuralist approach to endogenous money are the issues of the slope of the supply curves of reserves and of credit money, respectively (Fontana, 2003). The PK debate has been useful in articulating the mechanics of the money supply process, but inadequate attention has been paid to the implications of endogenous money for interest rate determination, the business cycle, and economic growth.

2.3.2 Endogenous Money and its Relation to Macroeconomics

Figure 4 provides a scheme for developing an endogenous money macroeconomic research agenda (Palley, 2008). An important feature of this scheme is that it is a loop with no beginning or end. The representation in terms of a loop is intended to capture the idea that the macroeconomic process is affected by the policy regime, and the policy regime in turn responds to the macroeconomic process.

An endogenous money perspective immediately raises concerns with debt

since bank lending is an important driver of money supply. Additionally, it raises questions about the determination of interest rates.

The horizontalist approach represents interest rates as being under the control of the monetary authority. However, the reality is that central banks set the overnight money market interest rate which has the greatest influence on short-term bank loan rates. Beyond that there is an array of different interest rates and asset prices, with interest rates varying by term to maturity and degree of credit risk. That raises the question of whether endogenous money introduces new theoretical issues regarding the term structure of interest rates and the pricing of commercial bonds of different credit risk? Additionally, does it raise new questions about the pricing of equities?

With regard to debt, there is the question of how debt impacts aggregate demand, and how it affects the economy's ability to reach full employment through price and nominal wage adjustment. Endogenous money is also relevant for business cycle analysis. Recently, there has been much interest generated on the effects of debt on business cycle but so far, little attention has been paid to the specific impact of endogenous money on the cycle. An exception is Palley (1997) who argues that endogenous money increases the amplitude of the business cycle. Endogenous money is also likely important for growth, providing a monetary mechanism that propels real growth by financing the growth of AD.

2.3.3 Pure Loan Demand and Mixed Portfolio-Loan Demand Models

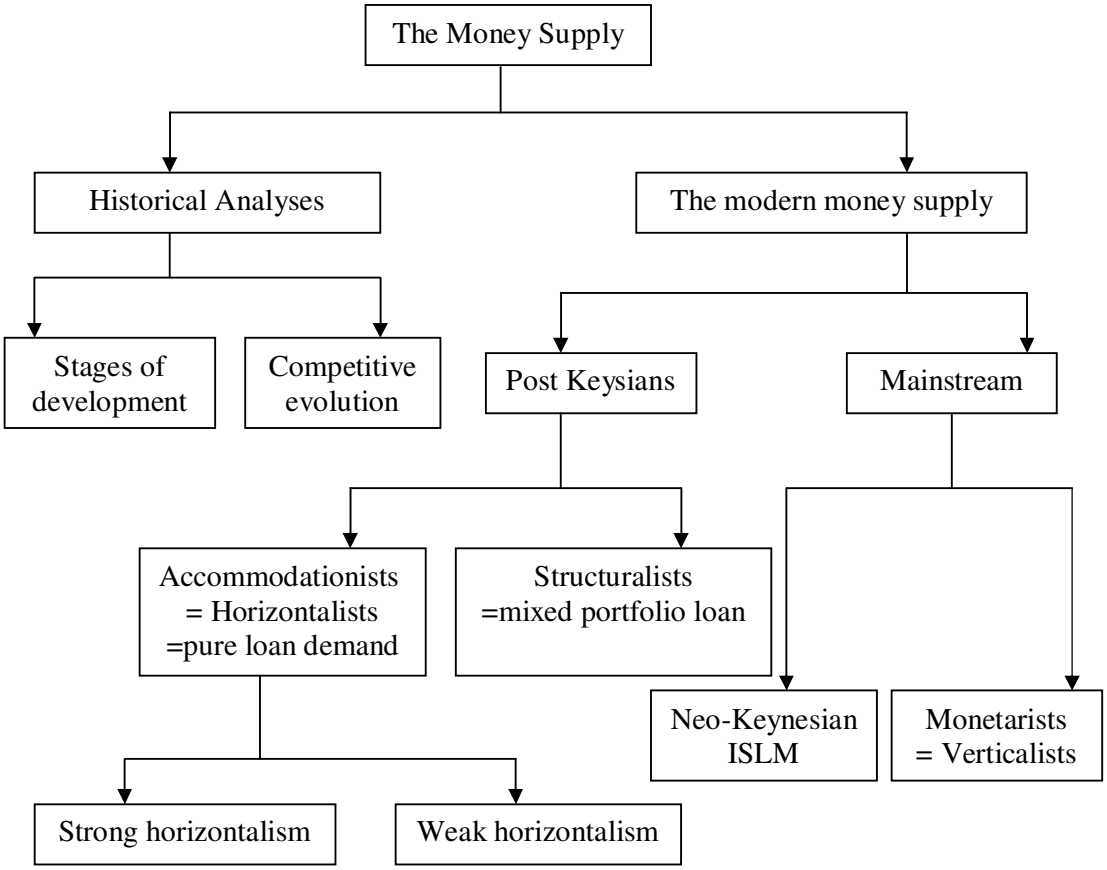
Palley (1993) describes that there are three competing models of the money supply process. The first model, the pure portfolio approach, corresponds to the orthodox description of the money supply process. The second model, the pure loan demand approach, corresponds to the PK accommodationist view of endogenous money. The third model, the mixed portfolio loan demand approach, corresponds to the PK structuralist view of endogenous money (Pollin, 1991). This third model is very much in the spirit of the earlier "New View" developed in the 1960's. However, the model explicitly focuses on the money supply implications of the banking system's response to expansionary shifts of loan demand. The earlier New View theorists emphasised asset substitutabilities, and focused on changes in asset prices. This was consistent with their interest in the monetary transmission mechanism, but they took money supply to be exogenous. PK focuses on the implications of asset substitutabilities for money supply, and the capacity of the banking system to underwrite economic activity.

The critical difference between the "pure loan demand" and "mixed portfolio-loan demand" models concerns the significance ascribed to the private initiatives of banks in accommodating increases in loan demand. In the pure loan demand model, accomodation depends exclusively on the stance of the monetary authority, and its willingness to meet the reserve pressures generated by increased bank lending. However, mixed model accommodation depends on both the stance of the monetary authority, and the private initiatives of banks. These initiatives are independent of the monetary authority, and are therefore suggestive of the structurally endogenous nature of "finance capital".

Palley (1994) shows how banks can expand broad money on an unchanged

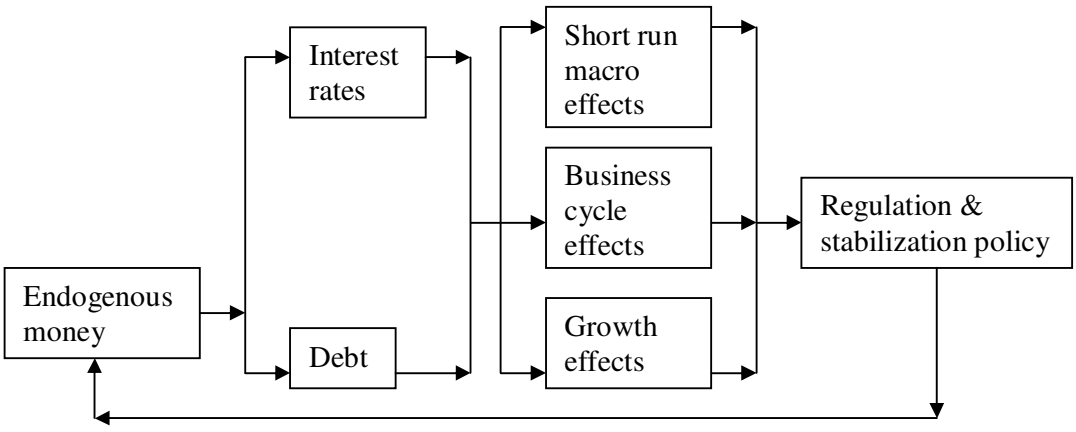
base. Changes in bank assets imply a change in broad money supply.

Figure 3 The Money Supply Process



Source: Palley（1993, 2008）

Figure 4 A Framework for Conceptualising Endogenous Money and its Relation to Macroeconomics



Source: Palley（2008）

2.4 Empirical Literatures

There are some empirical studies regarding money supply issues. Nell(1999) found that irrespective of the monetary system at the time, the money supply process in South Africa is endogenously determined. The empirical analysis further shows that the inability of the South African Reserve Bank (SARB) to reach predetermined M3 monetary growth targets on a consistent basis since the mid 1980s, is the direct result of an endogenous money supply and not, as a previous study claims, because of an unstable M3 velocity. Although the M3 velocity is stable over the whole period of 1966-1997, money income determined an endogenous money supply, so that the M3 money supply lost its effectiveness as a leading indicator for monetary policy. The policy implication is that the SARB controlled the M3 money supply indirectly over the period 1980-1997, through an increase in interest rates, and at the potential cost of a slowdown in economic activity.

Model simulations show that interest rates, the required reserve ratio, and a direct quantity control rule of the base money supply are most effective instruments in affecting monetary aggregates and prices but are least effective in affecting the real economy in the long run (Qin, Quising, He, Liu, 2005). Adjustments in PBC's various assets and liabilities have different effects on the money multiplier, and on money supply as a consequence (Li and Zhang, 2008).

Zatul E. Badarudin, Ahmed M. Khalid and Mohamed Ariff (2009) show that money supply is endogenous in five economies, namely China, the Czech Republic, India, Malaysia and Turkey while exogenous in Mexico. There was no causality found in Indonesia, Russia and Chinese Taipei. Thailand showed endogeneity in the long-run causality.

3. Theoretical Model

According to the spirit of the New View and PK theory, the complete model of the monetary base and money supply needs to consider the interactions of the following three parts.

（i） Bank behaviour

Bank behaviour relies on an explicit specification of a maximum profit-seeking and risk-averse model which describes the determinants of the supply of deposits by banks as well as their demand for earning assets and （free） reserves. n this paper, we will set up a model to solve the optimal values of a bank's investment, deposit interest rate, loan interest rate and free reserves.

（ii） The public sector

The public asset choice behaviour is set up exgoneously describing the determinants of the demands for currency and bank liabilities.

（iii）Central bank behavior

Monetary policy rules of the form proposed by Taylor (1993) are unsuitable for the monetary-targeting regime in Chinese Taipei. Chinese Taipei's central bank targets the money supply and uses the monetary base as the operating target. The Central Bank controls M2 annual growth rate within the target range to achieve its intermediate target and thereby affecting price and the economy. Therefore, central bank behaviour will be set up exogeneously to describe how the central bank affects monetary base. The central bank can control the monetary base and achieve its intermediate target.

With the above-mentioned structural model, we can derive the monetary base equation which is determined by various financial and real variables. Therefore, we will generate a multi-period bank decision model. The model will then be combined with the public and central bank equations to form a structural model of monetary base. These will be simultaneous equations that jointly describe the relationship between a set of variables.

3.1 Theoretical Model of Bank's Liquidity Management

In this section, we will construct a multi-period bank's decision model. It is assumed that the bank has influence in the local market in determining deposit and loan interest rates which in turn affects deposit and loan volumes. The bank is assumed to be risk averse and maximise the expected utility function of profits subject to adjusting behaviour of free reserves. We use the stochastic dynamic programming method to solve the optimal values of the bank decision variables.

The bank's revenues are assumed to be derived from returns in investments, loans, interbank loans and free reserves. Interest expenses are the main expenditure. All other expenses including personnel, sales and management are viewed as constant. Banks usually fund themselves through deposits and lend or invest them in long term assets. They will also borrow and lend at the interbank market when they have a surplus or shortage.

Our structural money supply model assumes risk-averse banks. The model of maximising expected utility function of profits subject to adjusting behaviour of free reserves can be written as:

$$\underset{(\tilde{r}_D,\tilde{r}_L,I)}{\text{Max}} \sum_{t=0}^{T-1} \beta^t EU(\tilde{\pi}) + \beta^{T-1} S(FR_T) \qquad (3.1)$$

Subject to:

$$\tilde{FR}_{t+1} = FR_t + \tilde{D}_t(1-z) - I_t - \tilde{L}_t - \tilde{F}_t + CA_t \qquad (3.2)$$

$$= FR_{t+1} + \mu_{FR}$$

Where

t=0,1,2,-----,T-1

$0<\beta<1$ is the time-discount factor or the inverse of the rate of time preference

E：the expectation operator.

U(・)：CARA（constant absolute risk aversion）utility function

$\tilde{\pi}$：profit

FR：free reserves

$\tilde{FR}_{t+1}$：terminal free reserves

$\mathrm{FR_t}$：initial free reserves

FR_{t+1}: average terminal free reserves

$\tilde{D}$：deposit

z：required reserve ratio

I：investment

$\tilde{L}$：loan

$\tilde{F}$：interbank loan（expressed in NT dollars），lend to other banks for $\tilde{F} > 0$ and borrow from other banks for $\tilde{F} < 0$.

CA：net capital account

$\tilde{r}_D$：interest rate on deposits

$\tilde{r}_L$：interest rate on loans

$\tilde{r}_I$：rate of return of investment

r_F：interest rate on interbank loans

r_R：rate of return of free reserves（can be positive or negative. It's negative when there is no interest for holding free reserves.

For notational simplicity, we skip the subscript t for the variables $\tilde{D}$, $\tilde{L}$, $\tilde{I}$, $\tilde{F}$, CA except the variable $\mathrm{FR_t}$.

Therefore, the bank's profit can be written as follows:

$$\begin{aligned}\tilde{\pi} &= \tilde{r}_I I + \tilde{r}_L \tilde{L} + r_R \tilde{FR}_{t+1} + r_F \tilde{F} - \tilde{r}_D \tilde{D} \\ &= (\mathrm{r_I} + \mu_{\mathrm{r_I}})\mathrm{I} + \mathrm{r_L}(\mathrm{L} + \mu_{\mathrm{L}}) + \mathrm{r_R}(\mathrm{FR_{t+1}} + \mu_{\mathrm{FR}}) + \mathrm{r_F}(\mathrm{F} + \mu_{\mathrm{F}}) - \mathrm{r_D}(\mathrm{D} + \mu_{\mathrm{D}}) \quad (3.3)\end{aligned}$$

Where

$\mathrm{D,L,F},r_D, r_L, r_I$： the average of $\tilde{\mathrm{D}}, \tilde{\mathrm{L}}, \tilde{\mathrm{F}}, \tilde{\mathrm{r}}_{\mathrm{D}}, \tilde{\mathrm{r}}_{\mathrm{L}}, \tilde{\mathrm{r}}_{\mathrm{I}}$.

$\tilde{D}$, $\tilde{L}$, $\tilde{F}$, $\tilde{r}_I$ are independent and identically distributed (iid) random variables. $\mu_{\mathrm{D}}, \mu_{\mathrm{L}}, \mu_{\mathrm{F}}, \mu_{\mathrm{r_I}}$ are the error terms of the individual variables respectively. Their means are zero and variances are $\sigma^2_{\mathrm{D}}, \sigma^2_{\mathrm{L}}, \sigma^2_{\mathrm{F}}, \sigma^2_{\mathrm{r_I}}$ respectively.

Terminal free reserves can be written as follows：

$$\begin{aligned}\tilde{FR}_{t+1} &= FR_t + \tilde{D}(1-z) - I - \tilde{L} - \tilde{F} + CA \\ &= (\ \mathrm{FR_t} + \mathrm{D}(1\text{-z}) \text{-I-L-F+CA}) + (\mu_{\mathrm{D}}(1-\mathrm{z}) - \mu_{\mathrm{L}} - \mu_{\mathrm{F}}) \\ &= \mathrm{FR_{t+1}} + \mu_{\mathrm{FR}}\end{aligned}$$

Where

μ_{FR} is the average terminal free reserves' error term with mean zero and variance σ^2_{FR}.

Mean and variance of the profit can be written as follows respectively：

$$E(\tilde{\pi}) = (r_I - r_R)I + (r_L - r_R)L + (r_F - r_R)F + [r_R(1-z) - r_D]D + r_R(FR_t + CA)， \quad (3.4)$$

$$Var(\tilde{\pi}) = I^2\sigma^2_{rI} + (r_L - r_R)^2\sigma^2_L + (r_F - r_R)^2\sigma^2_F + [r_R(1-z) - r_D]^2\sigma^2_D + L^2\sigma^2_{rL} + D^2\sigma^2_{rD} \quad (3.5)$$

Let S（FR_T）be the terminal or scrap value of the initial free reserves at the terminal period T and can be viewed as the terminal condition of the dynamic programming problem. S（FR_T）is assumed to be the concave function as follows：

$$S(FR_T) = \theta_1 FR_T - \theta_2 FR_T^2 \quad (3.6)$$

Where

$\theta_1 > 0, \ \theta_2 > 0$

The dynamic programming method views the multiperiod programming problem as a sequence of a simple choice problem. According to the Bellman Principle of Optimality, we need to define a Value Function V（·，t+1） to solve Equation（3.1）. The Value Function summarises the expected future utility at any decision period, assuming that an optimal policy will be followed in the future. The Value Function enables one to decentralise a complicated multiperiod decision problem into a sequence of simpler static decision problems. In this paper, the Value Function V（·，t+1）is V（FR_t）that satisfies：

$$V(FR_t) = Max\left\{E(\tilde{\pi}_t) - \frac{Z}{2}Var(\tilde{\pi}_t)\right\} + E\left[\theta_1 F\tilde{R}_{t+1} - \theta_2 F\tilde{R}^2_{t+1}\right] \quad (3.7)$$

Where

Z：risk preference parameter

The terminal condition can be written as：$S(FR_T) = \beta V(FR_T)$

i.e. $\beta EV(FR_{t+1}) = ES(FR_{t+1}) = E\left[\theta_1 F\tilde{R}_{t+1} - \theta_2 F\tilde{R}^2_{t+1}\right]$; (3.8)

According to the dynamic programming principle, the bank's decision problem can be written as follows：

$$V(FR_{T-1}) = Max\left\{E(\tilde{\pi}_{T-1}) - \frac{Z}{2}Var(\tilde{\pi}_{T-1})\right\} + E\left[\theta_1 F\tilde{R}_T - \theta_2 F\tilde{R}^2_T\right] \quad (3.9)$$

$$s.t: \ F\tilde{R}_T = FR_{T-1} + \tilde{D}_{T-1}(1-z) - I_{T-1} - \tilde{L}_{T-1} - \tilde{F}_{T-1} + CA_{T-1} \quad (3.10)$$

The adjustments of the interest rate on deposit and loan and the demand of investment assets are the asset and liability management business of the bank after

interest rate liberalisation. Our model's decision variables are interest rate on deposit (r_D) and loan (r_L) and the demand of investment assets (I). Before solving the optimal values of I_t^*, $r_{L,t}^*$ and $r_{D,t}^*$, we need to solve the optimal values of the decision variables at the period of T-1 (i.e. I_{T-1}^*, r_L^{T-1}, r_D^{T-1}), and subsequently solve the value function at the period of T-1 (i.e. $V(FR_{T-1})$). The optimal values of I_t^*, $r_{D,t}^*$ and $r_{L,t}^*$ are as follows respectively:

(1) The optimal value of investment:

$$I_t^* = \frac{1}{-2\beta\phi_{t+1} + Z\sigma_{r_I}^2}\{r_I - r_R - 2\beta\phi_{t+1}[FR_t + (c + dr_D)(1-z) + CA - F - (a + br_L)] - \beta\delta_{t+1}\} \tag{3.11}$$

Or

$$I_t^* = i_1 r_{I,t} + i_2 r_{R,t} + i_3 r_{D,t} + i_4 r_{L,t} + i_5(FR_t + CA_t - F_t) + u_I, , \qquad (3.11\text{-}1)$$

Where

$i_1 = \Omega > 0$,
$i_2 = -\Omega < 0$,
$i_3 = -2\Omega\beta\phi_{t+1} d(1-z) > 0$,
$i_4 = 2\Omega\beta\phi_{t+1} b > 0$,
$i_5 = -2\Omega\beta\phi_{t+1} > 0$,
$u_I = -2\Omega\beta\phi_{t+1}[(1-z) - a - \beta\delta_{t+1}]$,

i.e.

$$\frac{\partial I_t^*}{\partial r_I} > 0, \frac{\partial I_t^*}{\partial r_R} < 0, \frac{\partial I_t^*}{\partial rD} > 0, \frac{\partial I_t^*}{\partial r_L} > 0, \frac{\partial I_t^*}{\partial FR} > 0,$$

(2) The optimal value of interest rate on loan

$$r_{L,t}^* = \ell_1 r_{I,t} + \ell_2 r_{R,t} + \ell_3(FR_t + CA_t - F_t) + \ell_\mu, \tag{3.12}$$

With

$\ell_1 > 0, \ell_2 \underset{<}{\geq} 0, \ell_3 < 0$;

(3) The optimal value of interest rate on deposit

$$r_{D,t}^* = \tau_1 r_{I,t} + \tau_2 r_{R,t} + \tau_3(FR_t + CA_t - F_t) + \tau_\mu, \qquad (3.13)$$

With

$\tau_1 > 0, \tau_2 \underset{<}{\geq} 0, \tau_3 < 0$;

(4) The optimal value of free reserves

The optimal value of free reserves is obtained by substitution of I_t^*, $r_{L,t}^*$ and

$r^{*}_{D,t}$, i.e.（3.11）（3.12）and（3.13）into（3.2）：

$$\tilde{FR}^{*}_{t+1} = \psi_1 r_{I,t} + \psi_2 r_{R,t} + \psi_3 (FR_t + CA_t - F_t) + \psi_\mu, \qquad (3.14)$$

Where

$$\psi_1 = \{\tau_1[d(1-z) + 2\beta\phi_{t+1}\Omega] - \Omega\}$$
$$\psi_2 = \{\tau_2[d(1-z) + 2\beta\phi_{t+1}(1-z)\Omega + \Omega + \ell_2[-b - 2\beta\phi_{t+1}\Omega\}$$
$$\psi_3 = \{1 + 2\beta\phi_{t+1}\Omega + \tau_3[d(1-z) + 2\beta\phi_{t+1}\Omega(1-z)] + \ell_3[-b - 2\beta\phi_{t+1}\Omega b]\}$$
$$\psi_\mu = \{\tau_\mu[d(1-z) + 2\beta\phi_{t+1}(1-z)\Omega] + \ell_\mu[-b - 2\beta\phi_{t+1}\Omega b] + c(1-z) + u_D$$
$$+\beta\delta\Omega - a - u_L\}$$

Based on prior information and the way the model was set up, we expect $\Psi_1 \lessgtr 0, \Psi_2 > 0, \Psi_3 > 0$. Equation (3.14) is the reduced form of the Structural Equations of (3.11),(3.12) and（3.13）.

Banks seek to maintain certain desired ratios of excess reserves and borrowings（or free reserves）to total deposits and these desired ratios are functionally related to market interest rates and the discount rate. In attempting to adjust the actual reserve ratios to the desired ratios, the banks increase or decrease their holdings of earning assets, thus causing deposits to change. The Central Bank, in attempting to control the money supply, should then focus on free reserves. Banks wanting to maintain ideal free reserve positions is correlated with market interest rate, rate of return of free reserves and change of bank's funds according to (3.14).

3.2 The Structural Model of Monetary Base

In this paper, commercial bank behaviour is only one part of the structural model which combines three parts of the determinants of the monetary base. The other two parts are the public and the central bank behaviour. Chinese Taipei's central bank manages the monetary base to achieve its intermediate target. From the demand side, the monetary base or reserve money is defined as the sum of currency held by the public and reserves（including cash in vaults and deposits with central bank）held by financial institutions. From the supply side, the monetary base is the sum of the central bank's net foreign assets (FA) and net domestic assets (NDA).

FA + NDA = MBB

Where

FA：net foreign assets
NDA：net domestic assets
MBB：total monetary base

This accounting identity reveals that central banks can control the monetary base by managing holdings of domestic and foreign currency assets（Higgins and Klitgaard, 2004）. This definition assumes that the central bank has no foreign

currency liabilities, and that it has zero net worth. Technically, our equation should read: monetary base = net domestic assets + net foreign assets – net worth.

And

$MB = C_P + RU = C_P + FR + zD$

Where

MB：non-borrowed monetary base（total monetary base excluding borrowed reserves）. It is more directly controllable by the central bank.

C_P：currency held by the public
RU：non-borrowed reserves

Bank's balance sheet constraints：

$L + F + R + I = D + CA + BR$，

Where

R：bank's reserves
BR：borrowed reserves

The relationship among the above mentioned equations can be expressed as follows:

$$FA + NDA = MBB = C_P + R = C_P + FR_{t+1} + BR + zD$$
$$MB = C_P + RU = C_P + FR_{t+1} + zD$$
$$L + F + R + I + R = D + CA + BR \qquad (3.15)$$

The central bank's net foreign assets and net domestic assets, the public's currency demand and demand of bank's liabilities can be configurated as follows:

（1） Equation of Central Bank's Net Foreign Assets

FA = FA（e, CUA, CAP）

Where

e：foreign exchange rate
CUA：current account
CAP：capital account

（2） Equation of Central Bank's Net Domestic Assets

NDA=NDA (gd,cmi,trandep,steri)

Where

gd：government deposits
cmi：claims on financial institutions
trandep：deposits of financial institutions
steri：sterilisation variable, for example, securities issued by central bank

（3） Equation of the Public's Currency Demand

$$F_P = a_p + d_p r_D + i_p r_I + y_p Y + P_u \qquad (3.16)$$

（4） Equation of the Public's Demand of Bank's Liabilities

$$F_D = a_D + d_D r_D + i_D r_I + y_D Y + D_u \qquad (3.17)$$

Assuming

$$d_P, i_P, i_D < 0; d_D, y_P, y_D > 0$$

Therefore, the structural model of the monetary base will be obtained by combining four reduced form equations of bank liquidity management behaviour（i.e.（3.11）、（3.12）、（3.13）、（3.14））, equation of the public's currency demand（3.16）, equation of the public's demand of bank's liabilities（3.17）, central bank's monetary policy reaction function and MB equation. We need to solve the nine equations in the following simultaneous model：

$$I_t^* = \frac{1}{-2\beta\phi_{t+1} + Z\sigma_{r_I}^2}\{r_I - r_R - 2\beta\phi_{t+1}[FR_t + (c + dr_D)(1-z) + CA - F - (a + br_L)] - \beta\delta_{t+1}\} \qquad (3.11)$$

$$r_{L,t}^* = \ell_1 r_{I,t} + \ell_2 r_{R,t} + \ell_3 (FR_t + CA_t - F_t) + \ell_\mu, \qquad (3.12)$$

$$r_{D,t}^* = \tau_1 r_{I,t} + \tau_2 r_{R,t} + \tau_3 (FR_t + CA_t - F_t) + \tau_\mu, \qquad (3.13)$$

$$\tilde{FR}^*_{t+1} = \psi_1 r_{I,t} + \psi_2 r_{R,t} + \psi_3 (FR_t + CA_t - F_t) + \psi_\mu, \qquad (3.14)$$

$$F_P = a_p + d_p r_D + i_p r_I + y_p Y + P_u \qquad (3.16)$$

$$F_D = a_D + d_D r_D + i_D r_I + y_D Y + D_u \qquad (3.17)$$

FA = FA（e, CUA, CAP）
NDA=NDA (gd,cmi,trandep,steri)
MB = $C_P + RU = C_P + FR_{t+1} + zD$

We can derive the monetary base equation by use of the deposit supply function and clearing condition. The deposit supply function can be obtained by the substitution of I_t^*, i.e.（3.11）into（3.15）：

$$D^S = \frac{1}{2z(1-z)\beta\phi_{t+1}}\{zZ\sigma^2_{r_I}(F + L - CA) + (-2\beta\phi_{t+1} + Z\sigma^2_{r_I})FR_{t+1} - (2\beta\phi_{t+1}z)FR_t +$$
$$z(r_I - r_R) + z(-2\beta\phi_{t+1} + Z\sigma^2_{r_I})RU - (-2\beta\phi_{t+1} + Z\sigma^2_{r_I})(FA + NDA - C_P - BR) - z\beta\delta_{t+1}\},$$

(3.18)

The deposit supply function D^S (3.18) is seen to be a multiple of non-borrowed reserves, adjusted for currency demand, initial free reserves as well as other variables. It is the generalisation form of the equilibrium equation (D=RU/z) mentioned in most text books. D^S can be affected by the foreign exchange rate.

(3.18) is derived within a given price level. However, it can also be derived within the general price level. That is: equation of the public's currency demand expressed as $C_P = PF_P(r_D, r_I, Y)$ and free reseves expressed as $FR=PF_{FR}(r_I, r_R, FR_t + CA - F)$. P can be taken as given in the short run where the money market reaches equilibrium. This can be seen by taking into account the market-clearing condition $D^S = D^d = PF_D(r_D, r_I, Y)$. By rearranging terms and solving for MB, we can obtain the monetary base equation as follows:

$$MB = -Z\sigma^2_{r_I}\Omega[F + (a + br_L + u_L) - CA] - \frac{1}{z}[\Psi_1 r_I + \Psi_2 r_R + \Psi_3(FR + CA - F)]$$
$$+2\beta\phi_{t+1}\Omega FR_t - \Omega(r_I - r_R) + (\frac{1}{z} - 1)(a_P + d_P r_D + i_P r_I + y_P Y + P_u)$$
$$+\frac{1}{z}(FA + NDA - BR) + 2(1-z)\beta\phi_{t+1}\Omega(a_D + d_D r_D + i_D r_I + y_D Y + D_u) + \beta\delta_{t+1}\Omega,$$

(3.19)

Or

$$MB = m_0 + m_1 r_I + m_2 r_R + m_3 r_D + m_4 r_L + m_5 FR_{t+1} + m_6 CA_t + m_7 Y_t + u_m, \quad (3.20)$$

Where

$$m_0 = \frac{-z}{z-1}Z\Omega a\sigma^2_{r_I} - a_p - 2za_D\beta\Omega\phi_{t+1} + \frac{z}{z-1}\beta\delta_{t+1}\Omega,$$
$$m_1 = \frac{-z}{z-1}\Omega - i_p - 2z\beta\phi_{t+1}\Omega i_D \gtreqless 0,$$
$$m_2 = \frac{z}{z-1}\Omega < 0,$$
$$m_3 = -d_p - 2z\beta\phi_{t+1}\Omega d_D > 0,$$
$$m_4 = \frac{-z}{z-1}Z\Omega b\sigma^2_{r_I} < 0,$$
$$m_5 = \frac{-2}{z-1}\Omega\beta > 0,$$
$$m_6 = \frac{z}{z-1}Z\Omega\sigma^2_{r_I} < 0,$$

$$m_7 = -y_p - 2z\beta\phi_{t+1}\Omega y_D \gtreqless 0 \ ,$$

$$u_m = -P_u - Zu_L Ws_{r_I}^2 - 2zbf_{t+1} WD_u \ ,$$

(3.19) or (3.20) indicates that the monetary base which is determined by the central bank is affected by the bank's decision variables, central bank and the public. I In actual fact, it is affected by F, FA, NDA and other variables. Although the monetary base can be adjusted by the central bank's reaction function, it is endogenously determined.

4. Comparative Statics Analysis

(1) Open Market Operations

$$\frac{\partial MB}{\partial steri} = \frac{\partial MB}{\partial NDA}\frac{\partial NDA}{\partial steri} = \frac{1}{z} NDA'_{steri} < 0$$

Open market operations can affect MB. For example, central bank issuance of securities to absorb liquidity will reduce MB. Theoretically, the sign of the impact of the sterilisation on MB is negative. However, the actual sign will be dependent on data because of endogenous money.

(2) Rate Of Return of Investment

$$\frac{\partial MB}{\partial r_I} = m_1 + \frac{1}{1-z}\frac{\partial FR_{t+1}}{\partial r_I} = m_1 + \frac{1}{1-z}\Psi_1 = \frac{z}{1-z} - i_P - 2z\beta\phi_{t+1} i_D \Omega + \frac{1}{1-z}\Psi \gtreqless 0;$$

The impact of the rate of return of investment on MB is transmitted through deposit demand and currency demand by the public. The sign of the impact is not definite. Empirical studies indicate that the impact is negative (Moore, 1979) while theoretical papers show that it's inconclusive (Cornell, 1983).

(3) Required Reserve Ratio

$$\frac{\partial MB}{\partial z} = -Zb\sigma_{r_I}^2 \Omega \frac{\partial r_L}{\partial z} + \frac{1}{z^2} FR_{t+1} - \frac{1}{z}\frac{\partial FR_{t+1}}{\partial z} - (\frac{1}{z} + \frac{1-2z}{z^2}) F_P - \frac{1-2z}{z^2}(d_P \frac{\partial r_D}{\partial z})$$
$$- \frac{1}{z^2}(FA + NDA - BR) - 2\beta\phi_{t+1}\Omega F_D + 2(1-z)\beta\phi_{t+1}\Omega(d_D \frac{\partial r_D}{\partial z});$$

Reserve requirements are one of the three monetary policy tools Central Bank, Chinese Taipei uses to implement monetary policy. In recent years especially, the Central Bank had sometimes employed changes in reserve requirements as a monetary policy tool, although open market operations are more commonly used. The impact of changes in reserve requirements is difficult to estimate; each change has the potential to affect thousands of financial institutions in different ways, depending on each institution's deposit base. Changes in reserve requirements also typically lead to changes in pricing schedules for some bank services as some bank fees and credits are

set based on reserve requirements.

A required reserve ratio increase will raise required reserves, reduce liquidity and tighten monetary policy. The sign of the impact of the required reserve ratio on MB is therefore negative. However, actual reserves usually have been changing along with required reserves in Chinese Taipei. Hence, the actual sign of the impact of the required reserve ratio on MB will be dependent on data because of endogenous money.

（4） Risk Preference Parameter

$$\frac{\partial MB}{\partial Z} = \left(-\sigma_{r_I}^2 \Omega + Z\Omega^2 \sigma_{r_I}^4\right)\left(F + L - CA\right) - Z\sigma_{r_I}^2 \Omega b \frac{\partial r_L}{\partial Z} + 2\beta\phi_{t+1}\Omega^2 \sigma_{r_I}^2 FR_t - \frac{1}{z}\frac{\partial F\tilde{R}_{t+1}}{\partial Z}$$
$$+\Omega^2 \sigma_{r_I}^2 (r_I - r_R) - \frac{1-2z}{z} d_P \frac{\partial r_D}{\partial Z} - 2(1-z)\beta\phi_{t+1}\Omega^2 \sigma_{r_I}^2 F_D + 2(1-z)\beta\phi_{t+1}\Omega d_D \frac{\partial r_D}{\partial Z}$$
$$-\beta\delta_{t+1}\Omega^2 \sigma_{r_I}^2$$

More risk-averse bank liquidity management may make MB higher. The impact of the risk preference parameter on MB is expected positively.

（5） Foreign Exchange Rate

$$\frac{\partial MB}{\partial e} = \frac{\partial MB}{\partial FA}\frac{\partial FA}{\partial e} = \frac{1}{z} FA_e' \gtreqless 0;$$

The central bank's net foreign assets are affected mainly by the balance of payment, foreign exchange rate and GDP. The sign of the impact of foreign exchange rate on net foreign assets is not definite.

5. Conclusions

In this paper, we develop a structural monetary base model which focuses explicitly on the role of bank liquidity management. An important feature of this approach is that the model combines three parts of the determinants of money supply. The three parts comprise the commercial bank, the public and the central bank. Bank behaviour relies on an explicit specification of a maximum profit-seeking and risk-averse model which describes the determinants of the supply of deposits by banks as well as their demands for earning assets and (free) reserves. The public asset choice behaviour is set up exgoneously describing the determinants of the demand for currency and bank liabilities. Central bank behaviour is generated exogeneously to describe how the central bank affects monetary base. According to the structural model, we derive the monetary base equation which is determined by various financial and real variables. Although the monetary base can be adjusted by the central bank's reaction function, it is endogenously determined.

Comparative statics analysis shows that open market operations can affect MB. The sign of the impact of the sterilisation on MB is negative. The sign of the impact of other variables on MB is inconclusive.

From a policy perspective, two points are worth emphasising（Rochon and Rossi, 2006）. First, the fact that money has always been endogenous may well explain the practical difficulties and shortcomings of any monetary targeting strategies in policy making. Secondly, the endogeneity of money implies that institutions have to come to terms with it.

In fact, as repeatedly pointed out by Goodhart (1994), "[i]f the central bank tried to run a system of monetary base control, it would fail". This sheds some light on the generalised preference for central bankers to adopt a monetary policy strategy based on a target for inflation rather than for a growth rate of a monetary aggregate such as M0, M2, or M3.

However, the Central Bank, Chinese Taipei is always able to achieve its announced monetary target. One reason for not achieving the announced target, on rare occasions, could be that money is endogenous. In a modern open economy with a sophisticated profit-maximising banking system, a non-banking financial sector, dynamic currency in circulation affecting the supply of bank reserves and rapid international capital flows, it is at least questionable whether money is exogenous Holtem¨oller, 2002）.

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